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ABSTRACT

A number of key issues facing elementary, secondary, and postsecondary educational administrators during retrenchment require a hierarchical decision-modeling approach. This paper identifies and discusses the use of a hierarchical multiple-alternatives modeling formulation (computer-based) that compares and evaluates a group of solution alternatives for (1) their feasibility as defined by the criterion constraints of the solution environment and (2) their individual contribution to the goals of the decision model. The application of this hierarchical multiple-alternatives model is illustrated with respect to three specific problem areas: (1) targeting of individual program budgets for graduated reduction; (2) consolidation of separate school districts into a unified district; and (3) selective analysis of individual schools in a district for subsequent closure, lease, sale, and/or mothballing. Finally, currently available computer programs are evaluated for their utility in hierarchical decision-modeling. Two pages of references are included. (TE)

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RETRENCHMENT IN EDUCATION: HIERARCHICAL DECISION MODELS FOR INSTRUCTIONAL PROGRAM TERMINATION, DISTRICT CONSOLIDATIONS AND SCHOOL CLOSURES

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Objectives

[1] Define and interpret a series of issues facing elementary, secondary and post-secondary educational administrators during retrenchment as requiring a hierarchical (levels-oriented) decision modeling approach;

[2] Identify and discuss the use of a hierarchical multiple alternatives modeling formulation (computer-based) which compares and evaluates a group of solution alternatives for (1) their feasibility as defined by the criterion constraints of the solution environment and (2) their individual contribution to the goals of the decisional model;

[3] Simulate and illustrate the application of this hierarchical multiple alternatives model to three specific problem areas: (1) targeting of individual program budgets for graduated reduction, (2) consolidation of separate school districts into a unified district, and (3) selective analysis of individual schools in a district for subsequent closure, lease, sale and/or mothballing; and,

[4] Evaluate and validate the use of market-available computer programs for their ability to exercise the option of hierarchical decision modeling.

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INTRODUCTION

Problems surrounding education's response to current retrenchment strategies (declining enrollments, dwindling fiscal resources, increasing pressures to identify, remediate or terminate substandard instructional programs) encompass a category of the decision sciences known as hierarchical modeling. The use of hierarchical modeling is necessary whenever a particular level (degree) of an optional (alternative) solution must be identified in addition to the particular alternative solution itself.

Redistricting attendance boundaries and the assignment of available schools during district consolidations, choosing whether to sell, lease, partition functionally or mothball a school which has been targeted for closure, and determining whether a program budget will be decreased or increased and by how much during fiscal cycle re-budgeting -- all reflect current educational problems which require a hierarchical decisioning approach. To evaluate and compare the thousands of possible solutions literally available to the educational decisionmaker requires a criterion-referenced scheme which allows for (1) the combined and permutated analysis of all possible alternative solutions, and (2) the competitive trade-off and preference environment fostered by the comparison of multiple alternatives across several criteria reflecting the goals of the school district or university.

With the exception of a brief interlude during the late 1960's, education has characteristically ignored the decision sciences (e.g. operations research and industrial engineering) due to the highly technical and mathematical nature of these approaches to evaluating the feasibility and optimality of various solution alternatives. Education continues to apologize today for any venture which reduces some part of an investigation to numerical quantities reflecting a particular social or human factorial event. Even the advent of computers has failed to persuade many high-level decisionmakers of the benefits in analyzing the myriad of available data for identifying, evaluating and selecting an optimal solution alternative from the untold thousands which may exist in combination and permutation with each other.

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With the judicious nomination of alternative hierarchical solutions, and the careful identification, scaling and measurement of pertinent criteria, many of the engineering approaches to analysis can be effectively and validly utilized in the educational context. One of these, binary (0-1) integer programming, has been continually researched and effectively applied by the author to a wide diversity of educational problems, ranging from the closure of elementary schools (Wisconsin, 1978) to the budget reduction issues of higher education (Oregon, 1982). Using the situational contexts of (1) school closures, (2) district consolidations and (3) budgeting reductions, this paper will demonstrate how each of these problems areas can be evaluated via a hierarchical decision modeling approach.

With the complex issues facing educational decisionmakers today, and with the marked increase in availability of computers and generic numerical analysis programs, the educational administrator has a formidable arsenal of techniques with which to develop and test multiple alternate solutions to such problems as described above. This presentation will discuss and illustrate how to employ the mechanics of this arsenal to the construction of solutions to the hierarchical problem in education, allowing the decisionmaker to operate with more independence and a greater structure of investigation into today's problems.

MISSION

The purpose of this paper is to define, develop and display a mathematical modeling formulation which has significant potential for exploring the myriad of decisions available to the school district officer when faced with such complex needs of educational retrenchment as: (1) the evaluation of school district campus sites for potential future closure, (2) the assignment of budgetary funding variances to individual district programs, and (3) the merging of several small school districts into a unified, consolidated district.

For example, an appropriate mission statement of such a model for targeted school site closures would be formulated as:

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> To design a system of alternative school closure options, accounting for differential levels of operational discontinuance or continuance for each school site evaluated, based upon likely scenarios for the future needs and demands of the school district and its community, which could be compared and evaluated against established policy standards, and instructional and administrative requirements, and which would result in the selection of which schools would be closed or allowed to remain open, and the level of that operational discontinuance or continuance, respectively.

Thus the hierarchical school closure model will successfully determine (1) what number of schools should be targeted for closure, (2) the disposition of those closed schools, and (3) what will be the operating level of those schools remaining open.

An appropriate mission statement of such a model for educational fiscal crisis budgeting would be formulated as:

> To design a system of alternative budgeting alternatives, based upon likely scenarios for the future needs and demands of the school district, and its individual campuses and/or programs which could be compared and evaluated against established policy standards, and instructional and administrative requirements, and which would result in the selection of which program budgets will be reduced, and by how much.

A system of seven (7) goals can also be stated which would support the adequate and appropriate accomplishment of this mission in crisis budgeting evaluations and assignments:

> Goal 1. Prepare, for each program budget, the types and amounts of budgeting reductions which could be reasonably applied to the program budget, and in addition, prepare a narrative which would best describe the program after each type/amount of reduction;
>
> Goal 2. Define, across all program budgets, those measures of criterion reference which would best describe the resource needs, program contributions to school district, and its individual campuses and/or program goals, and internal/external perceptions of the programs whose budgets are being evaluated;

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Goal 3. Select, for each criterion reference defined in Goal 2, the maximum (in the case of negative impact) and minimum (in the case of positive impact) effects to the school district, and its individual campuses and/or programs which are sought based upon the types of programs reduced, and the amounts of each of their reductions;

Goal 4. Assure, for each program being evaluated, that one and only one level (or type) of reduction (if any) is selected;

Goal 5. Determine which of the criterion comparison references, defined in Goal 2, will be utilized to guide the final selection of which budgets will be selected for reduction, and the amount of that reduction, in the event that multiple school district program reduction strategies become available to the distric superintendent, building principals and/or program administrators;

Goal 6. Validate, for each of the criterion references utilized for determining the final types and amounts of program reductions, the extent to which each of these criterion references significantly determined the final selection of those programs for reduction, and the amount(s) of those reductions; and,

Goal 7. Correlate, in terms of the programs chosen for reduction and the weights associated with each of these reductions, the final overall reduction strategy of the university and the accuracy with which the school district, and its individual campuses and/or programs can honestly trust the results of strategy.

Such a modeling technique allows the decisionmaker to utilize all available data and information for simulating the impact to the school district which alternative closure decisions per each individual site might provide, or for simulating the impact to the school district which alternative funding levels per each individual program might effectuate. In both the school closure as well as the budgeting variance case(s), this forecasting strategy includes the ability to control for interrelationships between discrete pairs of programs in contrasted schools, as well as among the collective impact of groups of programs with their individual levels of recommended resource support or funding. Finally, this modeling strategy allows the decisionmaker to vary the initial controls placed upon the model's mathematical structure, thereby simulating alternative decisional solutions based upon an ever fluid and transactional environment.

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Note: Due to the special nature of the district consolidation model, it's discussion will be treated separately in this paper, and appears in the final sections of this report.

BACKGROUND

School district officers and local school boards have been faced with the issue of school closures ever since the beginning decline in student enrollments during the early 1970's. With the baby boom of the late 1940's successfully completing high school in 1968-1972, school administrators looked ahead to these students' children repopulating the schools during the late 1970's and throughout the 1980's. Zero-population growth enthusiasts, the economy, and a general alteration in life style brought such hopes to a disasterous end. By the mid-1970's, many school districts had experienced nearly a 50 percent decline in their ADM (average daily membership). With the economy creating parallel problems in terms of public and private educational funding, the decision by 1977 in many school districts was to close schools. Unfortunately, no one in the position to implement such a strategy knew where to start, or how to proceed in the volative issue of school closures.

The historical record (see The Design, Implementation and Evaluation of Mathematical Modeling Procedures for Decisioning Among Educational Alternatives (Wholeben, 1980)) clearly indicates that processes which determined which schools would be closed were often devoid of clear prestated criteria for such decisions, often ambiguous as to how the criteria which were used were finally analyzed to produce the lists of schools for closure, and sometimes absenting both valid content and reliable process from the decisionmaking process. The most blatant episode reported refers to the school board who divided the district into four parts, and then appointed a citizens committee representative of each area with the charge to choose their own schools for closure and submit their list to the superintendent and board for final approval.

Nearly 10 years after the educational community finally attested to the problem of declining enrollments, little has been done which would systemati-

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cally analyze a school district for potential school closure targets. What is needed, but continues to be ignored, is a method for simulating the school district's evaluation and decisionmaking perogatives (viz. expected impact of levels of school closure(s) in terms of corresponding levels of resulting program effectiveness) beyond those provided by the more generally understood techniques of cost-benefit and cost-effectiveness analyses. Specifically, a model which could identify several alternative, operational discontinuance and continuance assignments for each school campus, and summarily choose which level of operation best fits the desires, needs and constraints of the total school district's environment, would significantly enhance the district's ability to deal effectively with problems of declining student enrollments and increasing operation and maintenance costs.

The model presented in this paper views the school district environment as one in which some number of schools must be targeted for closure as one of a dynamic nature, and where information entering the model is highly variable and must be updated regularly. In addition, any such dynamic modeling of a highly variable environment must be able to evaluate the changing feasibility of potential alternative decisions as the parameters for selecting these decisions (themselves) change.

Moreover, problems related to program budgetary requirements in both public and private education (identification, assignment and resulting influence) have also become a major part of the school district superintendent's scope of decisioning during the past several years.

In this case, a method is needed for simulating the district's budgeting environment (viz. expected impact of levels of funding in terms of corresponding levels of resulting program effectiveness) beyond those provided by the more generally understood techniques of cost-benefit and cost-effectiveness analyses. Specifically, a model which could identify several alternative funding assignments for each program, and summarily choose which funding level for which individual program across all collective programs best fits the desires, needs and constraints of the school district's environment, would significantly enhance the district's budgetary decisional requirements.

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The model presented in this paper views the crisis budgeting decisional environment as one of a dynamic nature, where information entering the model is highly variable and must be updated regularly. In addition, any such dynamic modeling of a highly variable environment must be able to evaluate the changing feasibility of potential alternative decisions as the parameters for selecting these decisions (themselves) change.

In 1978, a rather simple though comprehensive modeling approach was attempted in the initial targeting of specific elementary schools for future closure in a school district serving a population center of approximately 180,000 people in the State of Wisconsin. The model's results identified the number of schools which were to be recommended for closure, by name, and with supporting rationale for each school's selection. In 1981, a reformulized model was applied to the needs of a small school district in the State of Washington where the superintendent had to cut not less than 213 thousand dollars from an existing district budget of 893.5 thousand dollars (24 percent reduction) with an accompanying specific rationale for each of the individual program reductions which collectively formed the recommended fiscal roll-backs.

These models, and others developed by the author, represent reformulizations of operations research techniques which typically determine product distribution routes for transportation and personnel assignment strategies for product service delivery. The technical models themselves, commonly refered to as binary (1,0) integer programming formulations, are little more than systems of simultaneous linear inequalities and equations, whose dependent variables (i.e. the alternatives being evaluated and compared) take on the value of '1' for each alternative which is a member of the "solution set of alternatives", and the value of '0' otherwise. Constraints to this decisional process are represented in the form of linear inequalities and equations and the single, best solution then chosen from the range of feasible, alternative solutions through the deployment of a single vector sum known as the objective function value.

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TYPE OF MODEL

The technical description of the modeling formulation for determining which school sites will be targeted to remain open or be closed, and the extent of that closure, must include components of simulation modeling related to the model's ability to be hierarchical, fixed level, exclusive, exhaustive and simultaneous. The description of the modeling formulation for determining which program budgets will be targeted for a funding variance, and the extent of that variance (i.e. increase or decrease in funding), must also incluce these components of hierarchy, exclusivity, exhaustiveness and simultaneity, but requires a variable level modeling orientation as opposed to the fixed level of the school closure model.

Hierarchical Decision Modeling. A hierarchical decision model is one where the alternatives (range of potential decisions) represent levels of a decision, such as might be reflected in the questions:

> "How many schools should be closed, which ones, and therefore which schools should remain operational?"
>
> "What should be the disposition of those schools targeted for closure?"
>
> "Should there be any operational changes in the schools which remain open, and if so, what variance is warranted?"

In contrast, the budget modeling case addresses such questions as:

> "Which programs should be assigned a funding variance?"
>
> "Should that variance be an increase or decrease?"
>
> "To what degree should that increase or decrease be assessed?"

As will be discussed in a later section, the alternatives available to the model for determining either school site closures or budgetary variances for programs represent a comprehensive approach to very complex problems. In either case,

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each of these three levels of decisioning are adequately simulated and evaluated.

Fixed Level Options. Hierarchical modeling structures may be either fixed or variable level. Fixed level means that the lowest level in the alternative decisional hierarchy available for evaluation and comparison is the same in number and type for each of the alternatives identified in the highest level of the hierarchy. The model which identifies schools for future closure is a fixed level model, in that the same five (5) lower-level hierarchical alternatives (closure with sale, closure with lease, closure with mothballing, partitioning with lease, and continued full operation) are available for each of the school sites being modeled.

Variable Level Options. The budget reduction model is variable-level hierarchical, and as such allows different numbers and/or types of lower-level hierarchical alternatives across each of the higher-order alternatives. This represents the use of a graduated reduction scheme, in that some budgets may have several levels of percentage reductions being considered, while other have only a few. Some programs may be evaluated for potential increase in funding, while others have the simple alternative of remaining solvent at current funding levels (called zero-budgeting or stasis) or terminating their operations (100 percent funding reduction) in the future.

Discrete Options as Mutually Exclusive. In the hierarchical school closure model for school districts, two internal controls must be effectively implemented through model design.

First, each alternative option must be designed so as to represent a mutually exclusive relationship with each of the other options. Thus, if option 'a' includes some or all of the ingredients of another option, say 'b', then 'a' must be formulated with these ingredients internal to its own structure without the necessity of choosing 'b' in consort with 'a' if a combination of such ingredients are desired in the final solution. Furthermore, the characteristics of a must not be equivalent to 'b', although 'a' may contain all of 'b' in addition to other ingredients not found in 'b'.

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Second, the choice of a particular lower-order hierarchical option for each higher-order alternative must be singular, or discrete. Thus, choosing alternative 'a' must necessarily preclude any subsequent selection of 'b', 'c', ... for that particular higher-order alternative. Therefore, if school 'A' has five alternatives available to it (as we will explore later) in terms of varying levels of operational discontinuance (closed) or continuance (open) -- that is, a finite of lower order alternatives -- then the decision to "close the site and sell the real property associated with the site" must necessary preclude the model's subsequent choice of an alternative which leases the property under long-term agreements.

In the graduated budget reduction scheme for higher education, two internal controls must be effectively implemented through model design.

Again, each alternative option must be designed so as to represent a mutually exclusive relationship with each of the other options. Thus, if option 'a' includes some or all of the ingredients of another option, say 'b', then 'a' must be formulated with these ingredients internal to its own structure without the necessity of choosing 'b' in consort with 'a' if a combination of such ingredients are desired in the final solution. Furthermore, the characteristics of 'a' must not be equivalent to 'b', although 'a' may contain all of 'b' in addition to other ingredients not found in 'b'.

Also, the choice of a particular lower-order hierarchical option for each higher-order alternative must be singular, or discrete. Thus, choosing alternative 'a' must necessarily preclude any subsequent selection of 'b', 'c', ... for that particular higher-order alternative. Therefore, if program 'A' has three lower-order alternatives for funding reductions, say '3%', '5%' and '8%' options, then the model's determination of an 8 percent reduction must be identified as the selection of the '8%' option, and not the multiple selections of both the '3%' and '5%' options.

Grouped Options as Collectively Exhaustive. The hierarchical school closure model not only controls adequately for both of these "discrete" and "exclusive" factors, but in addition guarantees that all options are equivalently evaluated

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and each campus site assigned a resulting level of operational discontinuance or continuance based upon data available to the model. Not only does each school have a potentially variant number of options available for evaluation, but the set of variable level options assigned to each campus is exhaustive of all potentially reasonable (and unreasonable) alternative decisions which must be considered.

The budget reduction model guarantees that all options are equivalently evaluated and each program assigned a resulting funding variance dependent upon the data available for such comparisons. Not only does each program have a potentially variant number of options available for evaluation, but the set of variable level options assigned to each program is exhaustive of all potentially reasonable (and unreasonable) alternative funding variances which must be considered.

Identified Solutions as Feasible, Alternative and Simultaneous. The hierarchical school closure model and the budget reduction model identifies for district level administrators (if in actuality solutions exist) all possible subsets of alternative solutions which are feasible according to the constraints placed upon the model itself. These alternative subsets of available solutions that fit the decisionmaker's modeled constraints, i.e. are feasible, are guaranteed to not violate any of the constraints intially placed upon the model's formulation. Thus, all feasible, alternative solutions are said to be simultaneous -- simulataneously in compliance with all established modeling constraints.

COMPONENTS OF THE GENERIC MODEL

The mathematical formulations utilized for the school closure and graduated fiscal budgeting models are those of the Multiple Alternatives Model™ (Wholeben, 1980). MAM™ is a educationally oriented revision of binary (1,0) integer programming, and represents a mathematical system of linear inequalities and equations composed of:

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[1] two (1) label definition vectors (the alternatives and criteria labels vectors);

[2] one (1) rectangular matrix (the coefficient matrix);

[3] two (2) column data declaration vectors (the condition vector and bounded limits vectors), collectively known as the right-hand-side or RHS;, and

[4] one (1) row data declaration vector (the objective function).

Development of the multiple alternatives modeling system is performed in a strict sequence of activities, defined by the product which results from each particular activity. This developmental sequence is described below, including a brief statement of the function of that particular product for later system definition and modeling control.

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MULTIPLE ALTERNATIVES MODEL™

(Components)	(Functions)
ALTERNATIVES (LABELS) VECTOR	defines the discrete decision alternatives which will be compared and evaluated during the execution of the MAM™ model
CRITERIA (LABELS) VECTOR	defines the particular criteria which will direct the execution of the model in selecting those subsets of alternatives which are feasible as solutions under the criterion standards imposed
COEFFICIENT MATRIX	contains those values for each alternative (column) measured against each criterion standard (row) evaluating each alternative's comparative worth
RIGHT-HAND-SIDE (RHS)	composed of an algebraic condition ($\leq, =, \geq$) and a bounded limit, this component transforms the coefficient matrix into a system of linear inequalities and equations, known as the constraint matrix
OBJECTIVE FUNCTION	contains values of an unbounded vector which will be used to select which single subset of feasible alternatives provides the best (optimal) solution under the conditions imposed by the constraint matrix

The development of school closure and graduated crisis budgeting models from the more generic MAM™ framework is sequencial, and involves a number of design decisions according to the mandates of the particular decisional environment being modeled. To illustrate this, each section (or phase) of MAM™ development

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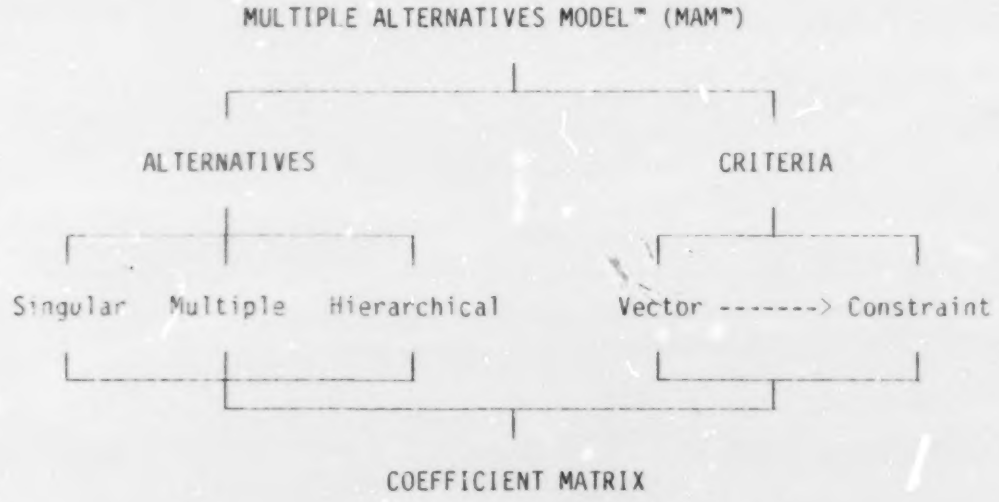
will be displayed in greater detail, and a number of comments related to crisis budget modeling offered to the reader.

The first stage of modeling development involves the design of the alternatives and criteria (labels) vectors in advance of gathering the necessary measures for incorporation into the coefficient matrix.



Both models require that a hierarchical approach be taken during alternatives vector design. As is true for all MAM™ designs, the development of each criterion vector must take into account its later use as a constraint (algebraic inequality or equality) for the evaluation, comparison and selection process.

Design and construction of the coefficient matrix requires the developer to first choose what type of vector/constraint is to be modeled; for example, a maximizing vector which will be utilized as a maximizer constraint, attempting to secure that mix of alternatives which maximizes some perceived good or benefit, as opposed to a minimizing vector which will be utilized as a minimizer constraint, attempting to secure that mix of alternatives which minimizes some perceived negative effect or injurious worth. Secondly, the developer must select what type, format and scaling of values for each vector will be utilized to display the positive or negative impact associated with each alternative's worth.

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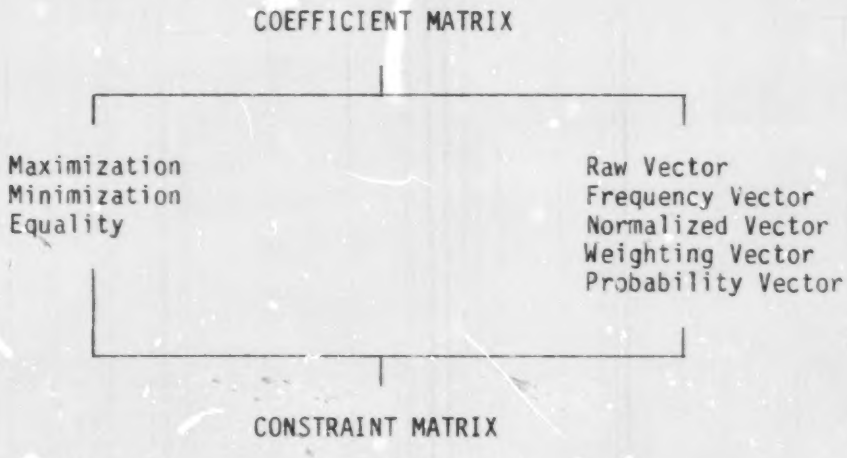

Both models utilize all three types of constraint conditions ($\leq, =, \geq$) and may employ each of the five measurement formats (raw, normal, etc.) available to the model based upon designer needs. Normalized and frequency (counting) vectors are the predominant choice for most budgeting situations. All four of the standard measurement scales (nominal, ordinal, interval and ratio) can be reliably introduced into the model.

The constraint matrix is simply a merger of the coefficient matrix and the right-hand-side (RHS) composite (condition vector and bounds vector), forming the system of linear inequalities and equalities which will constrain the final selection of the alternatives for membership within the solution set. Most problems associated with the proper use of the constraint matrix arise from an inappropriate development of the bounded values vector within the right-hand-side.

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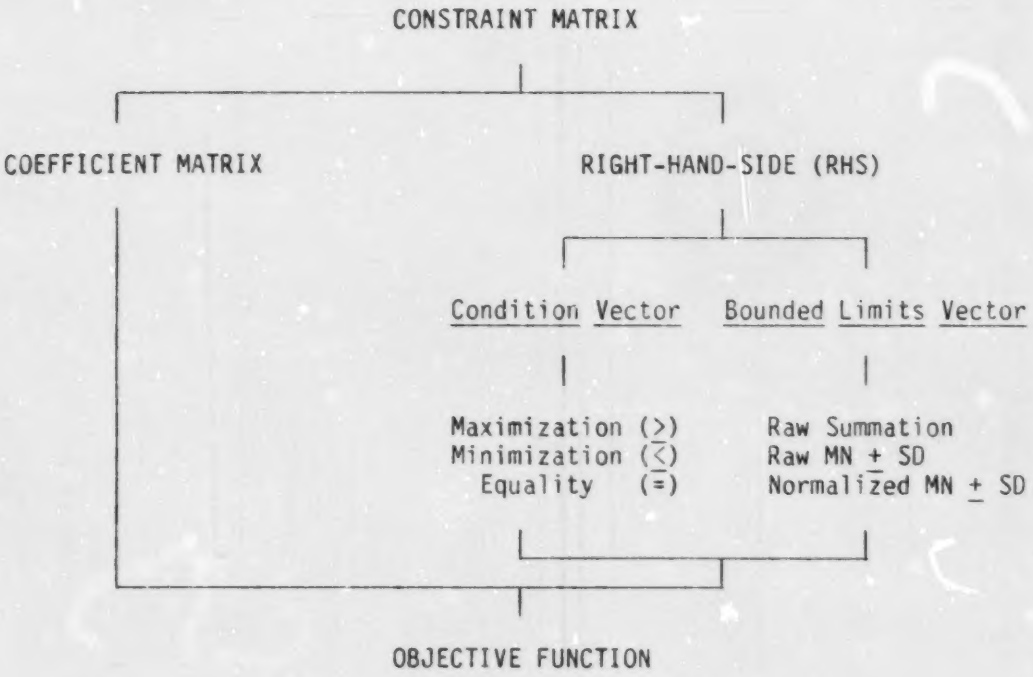

The use of normalized values for the coefficient matrix and the RHS is strongly recommended. Some criterion foci will have both raw and normalized vectors reflecting their influence upon the model, since raw values will control for specific criterion impact while the normalized transformations of these raw values will control for relative impact compared against the distributional qualities collectively of that particular criterion's measures.

The final component of the Multiple Alternatives Modeling™ framework for constrained decision selection is the objective function, or optimality vector. The objective function is either a raw or normalized values vector which is used to select the best (viz. optimal) subset of alternative solutions, from the larger subset of all feasible subsets of alternative solutions generated by the model. The use of a single objective function is known as singular-focused optimization, and is the conventional approach. Using several objective functions, and studying the impact upon the system by way of the different solutions selected by the model for each objective function used, is known as cyclic-focused optimization, and is the preferred approach.

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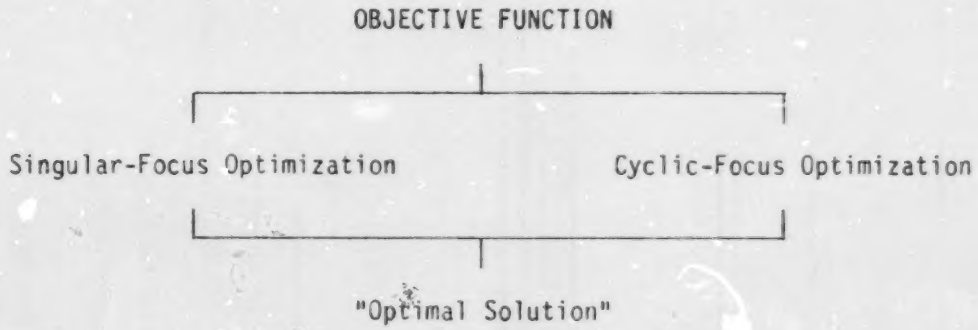

The school closure and graduated budgeting models employ the cyclic approach, and employs a wide range of both parametric and nonparametric statistics to perform post-hoc analyses on the variance in alternative solutions observed.

In summary, the general Multiple Alternatives Modeling™ framework employs a number of discrete vectors and a single rectangular matrix to operationalize the environment required for hierarchical decisionmaking for graduated crisis budgeting and resource assignment.

As a total system, the MAM™ may be illustrated as follows.

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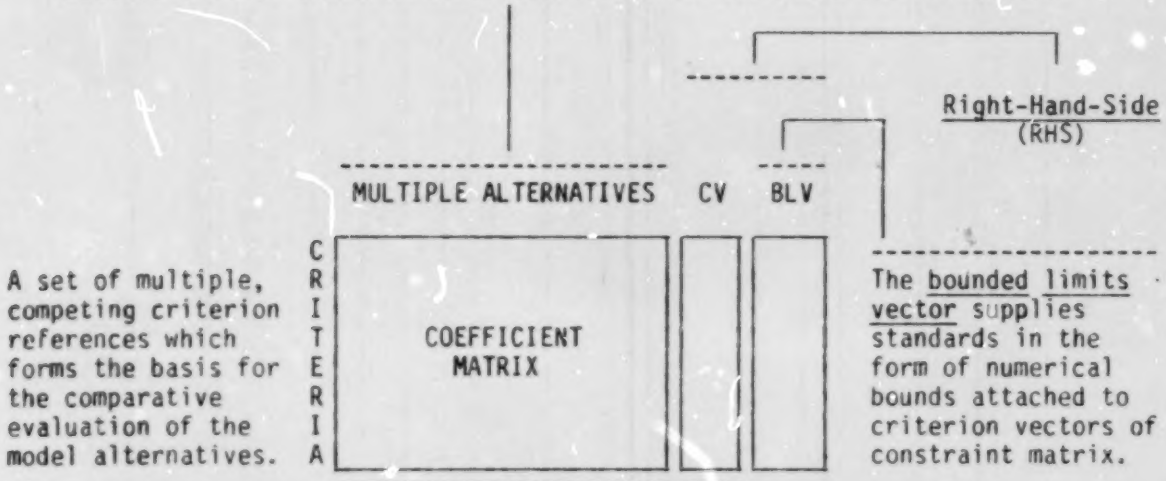
A collectively exhaustive set of mutually exclusive decisions which have been designated as comprehensively reasonable reactions to the problem situation identified; and from which a subset of decision alternatives may be drawn to construct the final solution set.


Right-Hand-Side (RHS)
MULTIPLE ALTERNATIVES
CV
BLV
CRITERIA
COEFFICIENT MATRIX
A set of multiple, competing criterion references which forms the basis for the comparative evaluation of the model alternatives.
The bounded limits vector supplies standards in the form of numerical bounds attached to criterion vectors of constraint matrix.
OBJECTIVE FUNCTION
The condition vector associates an algebraic inequality (≤,≥) or equality (=) with each vector and RHS pair to form a criterion-based constraint.

A set (or series of sets in the case of cyclic optimality) of criterion values in the form of linear terms which provides for the determination of the most optimal (i.e. the 'best') subset of decision alternatives in remediating the identified problem.

The vector portion (coefficients of the left-hand-side) which denote for each of the modeled alternatives (viz., the dependent variables), the value of each particular criterion's measure or influence (viz., the independent variables) related to that same particular alternative. Thus, the coefficients of each term in the linear inequalities represent the specific criterion measure for that particular term (i.e. alternative).

Recall that the use of the coefficient matrix in conjunction with the right-hand-side (RHS) provides the basis for formulating individual subsets of alternatives designated as feasible solutions (based upon the criterion constraints

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established through the simultaneous linear inequalities). These subsets of feasible solutions are then analyzed via the objective function(s) for the final determination of the single optimal solution subset.

To enhance the reader's understanding of not only the use of the MAM™ as a highly sensitive and specialized approach for targeting potential school closures or for crisis budgeting based upon program funding graduations, but also for viewing the MAM™ framework as a generalized technique for any situation which is data-based and includes discretely defined alternatives, subsequent sections will note those attributes of the hierarchical school closure and crisis budgeting MAM™ formulations which represent marked deviations from the conventional MAM™ formulation, as well as why such deviations were necessary.

THE DECISION ALTERNATIVES VECTOR FOR SCHOOL CLOSURES

The alternatives vector is a nominal vector, defining the hierarchical structure of the model, and naming each of the dependent variables (alternative dispositions of the school site if closed, or type(s) of continuance if left open and operational) available for evaluation and comparison. For the hierarchical school closure model, the structure of the alternatives vector is typically of two indices, the first naming the school being modeled, and the second defining the alternative dispositions of the campus based upon either targeted closure or targeted continuance of operations. Since this model is fixed-level hierarchical, the lower-order options will be identical in both number and type.

Alternative-j (j=1,...,n) ==> School Campus/Site				
Option-1	Option-2	Option-3	Option-4	Option-5

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where: Option-1 = target the site for future closure, and prepare the buildings for sale and relinquish of control;

Option-2 = target the site for future closure, and prepare the buildings for lease under district control;

Option-3 = target the site for future closure, and prepare the buildings of 'mothballing';

Option-4 = target the site for functional partitioning with partial physical units of the campus for lease; and,

Option-5 = target the site for continued full operation as an instructional center.

The determination of both the number and type of lower-order decisional alternatives in the hierarchical school closure model is based upon historical responses to the need to discontinue instructional operations at one or more school sites in districts such as Madison, Wisconsin and Seattle, Washington. The number and type of options advisable for any particular district could, and should, change the above alternatives vector to suit such individual needs. This model should never be operationalized before an extensive needs assessment within which the parameters of any potential closure decision(s) will be better understood. To better understand these five options, each will be explored in greater detail.

Closure and Sale. Depending upon the size and location of the school district, the option of selling a school after its closure has been one of the more typical alternatives. Many districts have neither the means nor the community demand to allow a creative use of a closed school plant. Therefore, the conventional approach is to attempt to recoup some amount of monies on their real property investment over the several preceding years, and use the monies from the sale of the plant to finance other competitive district needs. For more industrialized communities, and areas of population concentration where businesses and/or community service organizations vie for limited space on a

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cost-effective basis, a closed school (depending upon its physical condition) can be a very good investment.

Closure and Lease. In several instances, the district might foresee a future resurgence in public demand for the site as an instructional center (e.g. a future rise in enrollment over the short-run). Therefore the district is well advised to not relinquish control of the site. Schools are very expensive to build, and temporary discontinuance of operations over the short-term will prove beneficial if future needs for the site are predictable. In other situations, the district may gain school board approval to act in behalf of the district as a real property manager, making portions of the closed site available to local business concerns, service organizations, etc. under terms of fixed or variable term leasing. In this way, the district can build a marginal self-sufficiency of fiscal resources wherein leasing revenues can be used to support other district projects more instructional in their orientation.

Closure and Mothball. Whether predictable reopening for instruction in the future, ill-advised terms for available leasing agreements, or simply the non-availability of individuals for leasing or purchase of the site, the school plant can not be left in a state of inactivity for extended periods of time. Buildings deteriorate from lack of use -- dust, moisture, and temperature all militate to reduce the physical quality of a building more rapidly then if the school was over populated with students. The technique known as 'mothballing' prepares a building for an extended interim pause in operational use, but is not without its own expenses. The mothballing of a school plant is typically resorted to when the future use of the building can be foreseen in a matter of a few years. The most innovative mothballing techniques, with live-in caretakers, took place in Seattle, Washington in the early 1980s.

Functional Partitioning and Lease. A very utilitarian approach to school closures during periods of declining enrollments can be found in the redistribution of students by grade-level to different plant sites. For example, a district which might have generally configured its elementary and secondary schools as K-6 (elementary), 7-8 (middle) and 9-12 (high) may find it advisable to reconfigure (i.e. redistribute) the grade-level system as a K-3 (primary),

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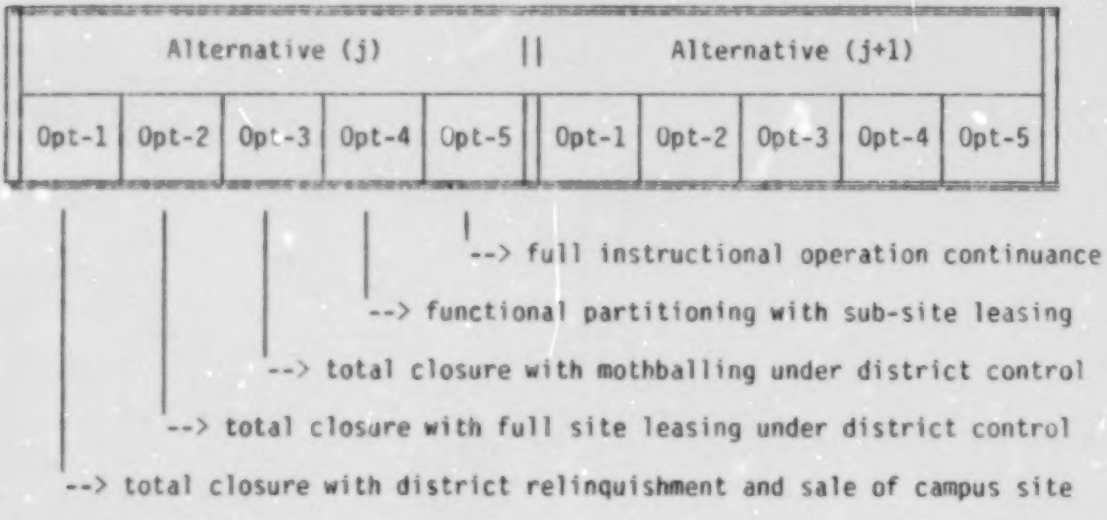
4-6 (elementary), 7-9 (junior) and 10-12 (senior) instructional operation, and on different school campus sites. Moving from a K-6 to a K-3 orientation, for illustration, might free as much as 60 percent of the plant for purposes of sub-site leasing to community service groups, etc.. This is known as functional partitioning of the instructional plant. A number of inherent problems are associated with this alternative, not the least of which are supervision, control and security. However, functional partitioning and sub-site leasing is a most viable alternative to full-site closure.

Full Operational Continuance. Finally, of course, there is the occasion of the school plant being sufficiently viable to sustain full instructional operation without the intervention strategies suggested in the previous four options.

An expanded view of the alternatives vector for the hierarchical school closure model is seen as follows:



In the original school closure (non-hierarchical) model, only two (2) options were evaluation modeled -- target the site for closure, or allow the school to remain operational -- and therefore only two choices available to the decisionmaker. The newer hierarchical model allows greater flexibility on the

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part of the district superintendent when declining enrollments and/or dwindling fiscal resources signal a need for austerity operations in terms of the physical school plant.

THE HIERARCHICAL SCHOOL CLOSURE MODEL

Precisely stated, this model seeks to:

> TARGET THE NECESSARY NUMBER OF SCHOOL CAMPUSES IN THE SCHOOL DISTRICT FOR FUTURE OPERATIONAL DISCONTINUANCE OR CONTINUANCE AND THE SPECIFIC LEVEL OF THAT DIS/CONTINUANCE, RESPECTIVELY (choosing from three pre-evaluated options for closure (i.e. including sale, leasing or mothballing) and two options for operational continuance (functional partitioning with sub-site leasing and full program continuance (no change)
>
> subject to:
>
> 1. maximizing the positive influence from all school-based programs, and their support administrative and physical plant structures, on total school district functioning, based upon final school-by-school closure levels selected;
>
> 2. minimizing the negative influence from all school-based programs, and their support administrative and physical plant structures, on total school district functioning, based upon final school-by-school closure levels selected;
>
> 3. assuring that all schools and their programs within the school district are nondiscriminantly evaluated, compared and constrasted to ascertain their contributing value or worth to the goals of the school district as a whole; and,
>
> 4. conclusively targeting levels of operational discontinuance or continuance based upon valid measures of effectiveness, expenditure, economy, efficiency, and satisfaction pertinent to the character of each school, and its instructional mission.

To accomplish this intent, a reformulation of the multiple alternatives modeling" framework (Wholeben, 1980) for hierarchical decisionmaking has been

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explored. Within the MAM™ context, the operational alternatives for each school are delineated into five (5) closure/non-closure options depending upon a pre-modeling evaluation of each school, and the resulting school options scenarios or narratives which result. Criteria, in the form of numerical vectors, are introduced within the model to (1) depict the pluses and minuses associated with each 'school closure' alternative, (2) compete for influence in the comparison and constrast of each 'closure' alternative with other likely options, and then (3) simulate the decisional environment of the school district, and its various service programs and/or instructional departments. This modeling approach to evaluating and selecting variant school closure alternatives based upon merit and estimated impact is MAM™ formulated as follows:

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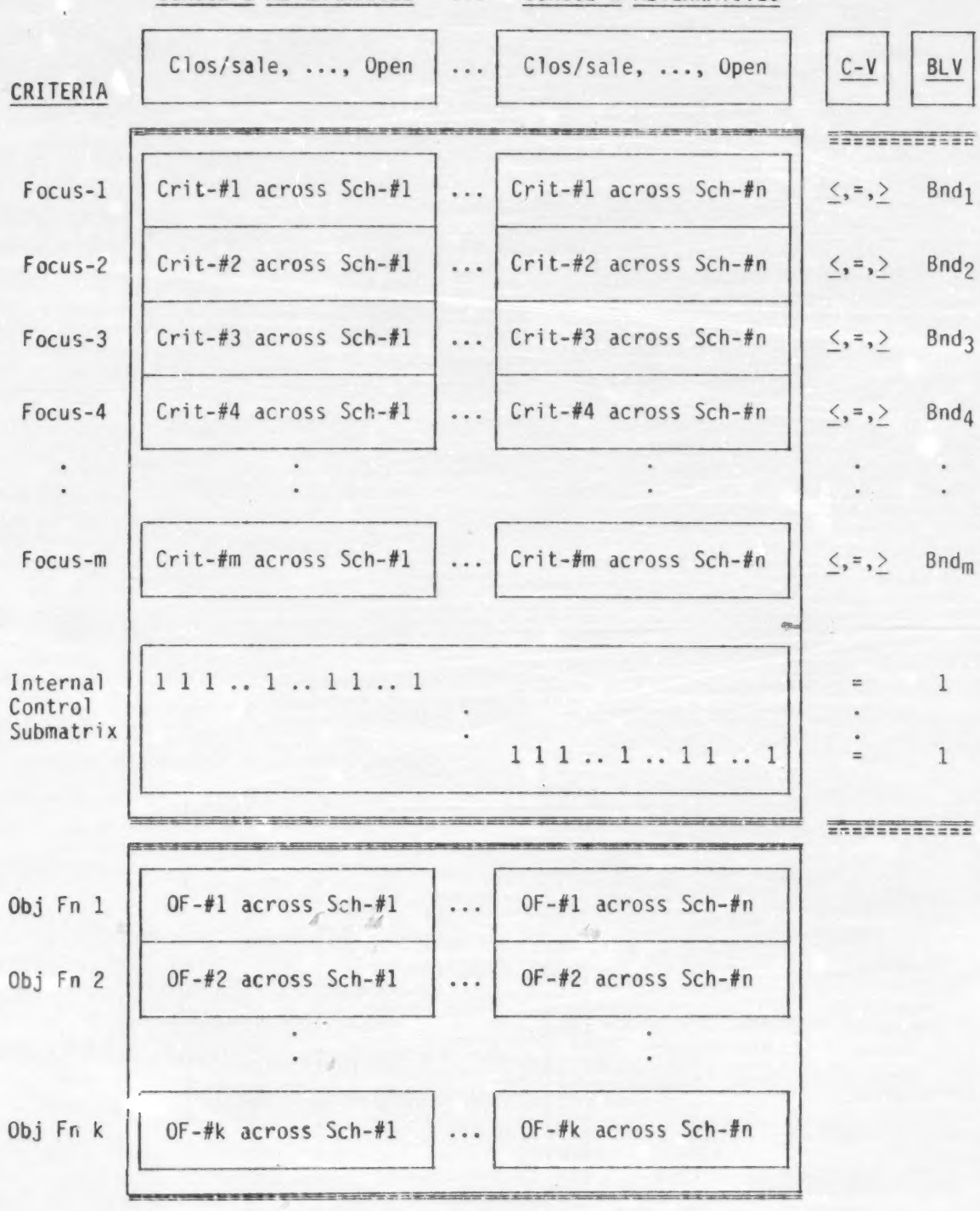
SCHOOL-1 ALTERNATIVES ... SCHOOL-n ALTERNATIVES
CRITERIA
Clos/sale, ..., Open
...
Clos/sale, ..., Open
C-V
BLV
Focus-1
Crit-#1 across Sch-#1
...
Crit-#1 across Sch-#n
≤,=,≥
Bnd1
Focus-2
Crit-#2 across Sch-#1
...
Crit-#2 across Sch-#n
≤,=,≥
Bnd2
Focus-3
Crit-#3 across Sch-#1
...
Crit-#3 across Sch-#n
≤,=,≥
Bnd3
Focus-4
Crit-#4 across Sch-#1
...
Crit-#4 across Sch-#n
≤,=,≥
Bnd4
Focus-m
Crit-#m across Sch-#1
...
Crit-#m across Sch-#n
≤,=,≥
Bndm
Internal Control Submatrix
1 1 1 .. 1 .. 1 1 .. 1
= 1
1 1 1 .. 1 .. 1 1 .. 1
= 1
Obj Fn 1
OF-#1 across Sch-#1
...
OF-#1 across Sch-#n
Obj Fn 2
OF-#2 across Sch-#1
...
OF-#2 across Sch-#n
Obj Fn k
OF-#k across Sch-#1
...
OF-#k across Sch-#n

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The reader should notice that the above depiction incorporates the use of cyclic optimization techniques for model execution. It is the author's view that cyclic optimization is superior to singular optimization (the use of a single objective function during alternatives evaluation) because of the additional information available for comparing and contrasting varying optimal solutions. Statistical techniques are available for performing such post-hoc analyses.

A diagrammatic insert (following this page) symbolically demonstrates the use of a criterion-based focus for modeling mandated policy guidelines (limits) across likely alternative school operational discontinuance or continuance scenarios. Although only ten criterion foci are modeled across the various school sites, each with fixed-level hierarchical closure options, it is more likely to expect a constructed model to evaluate a hundred or more criterion influences across the full complement of school sites in the district.

The criterion based influence within the model allows superior flexibility to the modeler for introducing the effect of certain influences on the final selection of a best-match (optimal) solution. Criteria reflecting measures of program effectiveness, expenditure, economy, efficiency and satisfaction are able to be input to the model for comparing and contrasting the individual impact of any one closure option, and that closure's contributing impact to the school district. These criterion influences may be based upon physical, transformation, definitional and/or synthetic datum bases, and entered into the model with any one or more of the typical nominal, ordinal, interval or ratio scale formats.

These criteria compete with each other for their influence in selecting the final solution -- a targeted closure or operational continuance level for each school site modeled.

To illustrate this criterion scaling, observe the following figure.

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	School Plant #1					...	School Plant #j					
	C/1	C/2	C/3	O/1	O/2	...	C/1	C/2	C/3	O/1	O/2	
Plant ADM Capacity				c_1	c_1	...				c_j	c_j	$\geq$ Futur Distr ADM
(expressed in students-count, from architectual blueprints)												
Plant ADA Vacancies				v_1	v_1	...				v_j	v_j	$\geq$ compd lower bound
(expressed in difference: plant capacity - plant ADM)												
School Prog Budgets				b_{14}	b_{15}	...				b_{j4}	b_{j5}	$\leq$ Distr Budg
(expressed in thousands of dollars, may be delineated by account)												
Anticipated Revenues	r_{11}	r_{12}		r_{14}		...	r_{j1}	r_{j2}		r_{j4}		$\geq$ compd lower bound
(expressed in thousands of dollars, may be delineated by source)												
Estimated Walk Dist	d_{11}	d_{12}	d_{13}	d_{14}	d_{15}	...	d_{j1}	d_{j2}	d_{j3}	d_{j4}	d_{j5}	$\leq$ compd upper bound
(expressed in average miles of site from attendance zones)												
Policy(s) Compliance	p_{11}	p_{12}	p_{13}	p_{14}	p_{15}	...	p_{j1}	p_{j2}	p_{j3}	p_{j4}	p_{j5}	$\geq$ compd lower bound
(expressed in frequency counts gathered through the scale below)												
Fails to Meet Most Requirements [1]												
Fails to Meet Some Requirements [2]												
Marginally Acceptable (Neutral) [3]												
Meets Most Requirements as Defined [4]												
Exceeds Most Requirements as Defined [5]												
Opinion from Survey(s)	o_{11}	o_{12}	o_{13}	o_{14}	o_{15}	...	o_{j1}	o_{j2}	o_{j3}	o_{j4}	o_{j5}	$\geq$ compd lower bound
(expressed in frequency counts gathered through the scale below)												
High Negative [1]												
Negative [2]												
More NEG Than POS [3]												
More POS Than NEG [4]												
Positive [5]												
High Positive [6]												
Administrator Preference	a_1	a_1	a_1	a_1	a_1	...	a_j	a_j	a_j	a_j	a_j	$\geq$ compd lower bound
(expressed in frequencies, respondents indicating preferred sites)												
Control #1	1	1	1	1	1							= 1
Control #2							1	1	1	1	1	= 1

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The reader's attention is called to a number of interesting albeit important contrasts between vectors in the above model. First, note that the first three criterion constructs (capacity, vacancy and budget) define coefficient matrix values for only the 'open' alternatives, while the fourth criterion constraint defines values for a subset of both 'close' and 'open' alternatives. In the first case, the importance of plant capacities, site vacancies, and required operating budgets is only germane if the plant/site is operating. Thus, these values need only be represented for the 'open' alternatives. Similarly, since revenues can only be expected if and only if the plant is available for some form of leasing or sale, only the first, second and fourth alternatives are germane to this standard.

In the case of the criterion 'estimated walking distance', a seemingly contradictory constraint is offerred wherein walking distance is defined for the closure options as well as the open alternatives. Such a strategy would be necessary is the modeler wish to directly target schools which had relatively large walking distances associated with it, rather than simply target schools for 'nonclosure' based upon relatively small walking distance measures.

While many other illustrations and/or examples are possible, the widely varying environment for targeting potential school closures nearly precludes the design of a 'conventional model' which would readily fit every school district's needs. The flexibility with which the model can be designed to fit very individualistic needs is both benefit and pitfall. While flexibility allows a model to conform strictly to needs peculiar to any individual modeling situation, this same flexibility forces the developer to re-think the model's formulation for each new school closure situation, especially as characteristics of supply and demand change to fit the fluid needs of a highly variant society.

THE DECISION ALTERNATIVES VECTOR FOR GRADUATED BUDGETING

The alternatives vector is a nominal vector, defining the hierarchical structure of the model, and naming each of the dependent variables (levels of budgeting variance) available for evaluation and comparison. For the graduated

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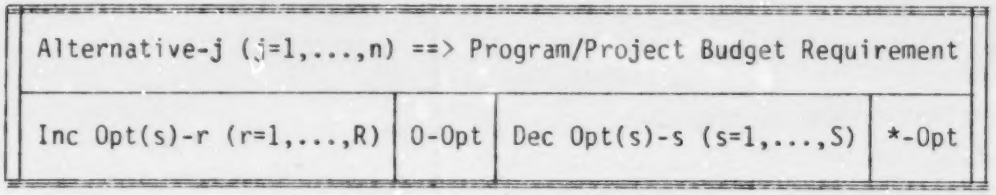
budget reduction model, the structure of the alternatives vector is typically of two indices, the first naming the program being modeled, and the second defining the alternative funding variances associated with each type of variance available for consideration. Since this model is variable-level hierarchical, the lower-order options will typically differ by both number and type.



Structured Budgetary Increase (Inc) Option which targets the program for a specified increase (in terms of a percent of current funding level) based upon the estimated impact of such an increase to the program's future operations in particular and to the organization as a whole

Program Termination (*) Option which targets the program for discontinuance and its budget for future absorption within the organization

Structured Budgetary Decrease (Dec) Option which targets the program for a specified decrease (in terms of a percent of current funding level) based upon the estimated impact of such a decrease to the program's future operations in particular and to the organization as a whole

Budget Stasis or Zero (0) Option which targets the program for continued funding at the current level of budgetary requirement

such that:

(1) R (number/type of increases in funding options) $\geq$ 0;

(2) S (number/type of decreases in funding options) $\geq$ 0;

(3) R not necessarily equal to S; and the

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(4) O-Opt and *-Opt options considered as comprehensively reasonable across all programs.

The determination of both the number and type of lower-order decisional alternatives in the graduated budget reduction model is a coterminous product of constructing a program options (funding level) scenario (viz. narrative) for each of the alternative levels of budgetary increase or decrease which seem reasonable based upon the specific, individual attributes of each program. Thus, an expanded view of the alternatives vector may be seen as follows.

Alternative (j)				Alternative (j+1)			
Inc Opt(s)	O-Opt	Dec Opt(s)	*-Opt	Inc Opt(s)	O-Opt	Dec Opt(s)	*-Opt
Increase(s) ..... Decrease(s)				Stasis ..... Term			

Options for budgetary variances need only be included in the model if such options are available to the decisionmaker. If no option(s) for funding increases or decreases are possible, the respective parts of the model should be eliminated.

Although stasis-budgeting and/or program termination may not be reasonable alternatives for the particular model, they must remain as feasible options. In this way, the model can more appropriately evaluate the full range of alternatives available to decisionmakers.

Stasis (i.e. 0 percent variance) and program termination (i.e. 100 percent reduction) must be considered reasonable program funding options for each and every program under evaluation. Although some programs may, whether socially or politically, be ultimately funded at a level inconsistent with the model's recommendations, the decisionmaker has the ability to at least initially survey a more objective interpretation of the data/information modeled during the decisioning simulation. Techniques are also available to force the model's consideration of a certain level of funding variance for a particular program, and thus include any negative as well as positive (beneficial) aspects of such a

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forced decisional selection upon the remaining more model-dependent options for other program budgets.

A more specific example of the way in which an alternatives vector would be formulated may be illustrated as follows.

Prog-01							Prog-02					Prog-03		...
+12	+03	0	-05	-12	-23	*	+07	+03	0	-15	*	0	*	...

<-------------------------------->
Program-01 has a wide variety of budgeting alternatives, including two options for increase and three options for decrease, in addition to the required alternatives of zero-budgeting (stasis) and complete termination of the program.

<---------------------->
Program-02 is more restricted than 01 in its available options, with two options for increase and only one avenue for decrease before the need for program termination.

<----------->
Program-03 is restricted to either funding at the current level, or the termination of the program.

Whether increase, decrease, stasis or termination, the number and type of funding level alternatives are based upon pre-organized information which identifies the characteristics of each such funding variance in terms of resulting program attributes. This description of the 'future' program under 'future' funding is known as the program options scenario, or funding level narrative.

THE GRADUATED PROGRAM BUDGET REDUCTION MODEL

Precisely stated, this model seeks to:

> **ASSIGN FUNDING VARIANCES TO ALL BUDGETS WITHIN THE UNIVERSITY (choosing from pre-evaluated funding decrease and increase options, including stasis budgeting and the possibility of full program termination)**
>
> **subject to:**

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1. maximizing the positive influence from all programs on total school district functioning, based upon final program-by-program budgeting levels selected;

2. minimizing the negative influence from all programs on total school district functioning, based upon final program-by-program budgeting levels selected;

3. assuring all programs within the university are non discriminantly evaluated, compared and contrasted to ascertain their contributing value or worth to the goals of the school district and,

4. conclusively targeting levels of funding based upon valid measures of effectiveness, efficiency, satisfaction and economy pertinent to the character of each individual campuses and/or its programs.

To accomplish this intent, a reformulation of the multiple alternatives modeling™ framework (Wholeben, 1980) for hierarchical decisionmaking has been explored. Within the MAM™ context, each school district program is delineated into several funding variant options depending upon a pre-modeling evaluation of each program, and the resulting budgeting (program options) scenarios or narratives which result. Criteria, in the form of numerical vectors, are introduced within the model to (1) depict the pluses and minuses associated with each program budgeting alternative, (2) compete for influence in the comparison and constrast of each funding alternative with other likely options, and (3) simulate the decisional environment of the district, and its various campuses and instructional departments. This graduated approach to evaluating and selecting funding alternatives based upon merit and estimated impact is MAM™ formulated as follows:

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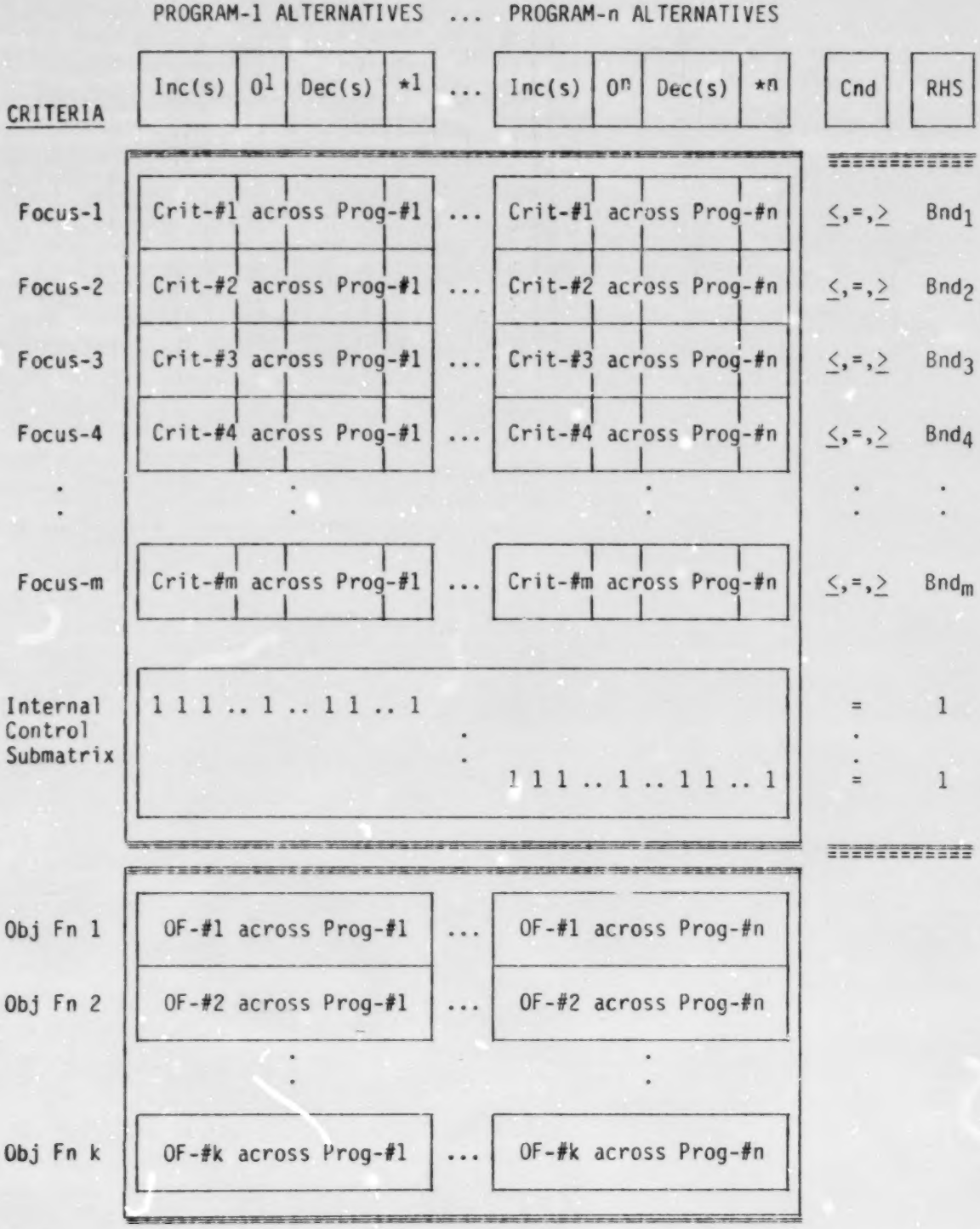
PROGRAM-1 ALTERNATIVES ... PROGRAM-n ALTERNATIVES
CRITERIA
Inc(s) | O1 | Dec(s) | *1 ... Inc(s) | On | Dec(s) | *n
Cnd
RHS
Focus-1 Crit-#1 across Prog-#1 ... Crit-#1 across Prog-#n ≤,=,≥ Bnd1
Focus-2 Crit-#2 across Prog-#1 ... Crit-#2 across Prog-#n ≤,=,≥ Bnd2
Focus-3 Crit-#3 across Prog-#1 ... Crit-#3 across Prog-#n ≤,=,≥ Bnd3
Focus-4 Crit-#4 across Prog-#1 ... Crit-#4 across Prog-#n ≤,=,≥ Bnd4
Focus-m Crit-#m across Prog-#1 ... Crit-#m across Prog-#n ≤,=,≥ Bndm
Internal Control Submatrix
1 1 1 .. 1 .. 1 1 .. 1 = 1
1 1 1 .. 1 .. 1 1 .. 1 = 1
Obj Fn 1 OF-#1 across Prog-#1 ... OF-#1 across Prog-#n
Obj Fn 2 OF-#2 across Prog-#1 ... OF-#2 across Prog-#n
Obj Fn k OF-#k across Prog-#1 ... OF-#k across Prog-#n

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As with the school closure model, the use of cyclic optimization techniques for model execution is recommended. It is the author's view that cyclic optimization is superior to singular optimization (the use of a single objective function during alternatives evaluation) because of the additional information available for comparing and contrasting varying optimal solutions. Statistical techniques are available for performing such post-hoc analyses.

A diagrammatic insert (following this page) symbolically demonstrates the use of a criterion-based focus for modeling mandated policy guidelines (limits) across likely alternative budgeting scenarios. Although only ten criterion foci are modeled across five programs, each with variable-level hierarchical funding options, it is more likely to expect a constructed model to evaluate a hundred or more criterion influences across several hundred program funding alternatives.

The criterion based influence within the model allows superior flexibility to the modeler for introducing the effect of certain influences on the final selection of a best-match (optimal) solution. Criteria reflecting measures of program effectiveness, efficiency, satisfaction and economy are able to be input to the model for comparing and contrasting the individual impact of any one program option, and that program's contributing impact to the university. These criterion influences may be based upon physical, transformation, definitional and/or synthetic datum bases, and entered into the model with any one or more of the typical nominal, ordinal, interval or ratio scale formats.

These criteria compete with each other for their influence in selecting the final solution -- a targeted funding level for each program modeled.

To illustrate this criterion scaling, observe the following figure.

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	Budget #1				Budget #2			Budget #3		
	00	15	25	**	00	05	**	00	**	
Personnel	$\$_{11}$	$\$_{12}$	$\$_{13}$	$\$_{14}$	$\$_{15}$	$\$_{16}$	$\$_{17}$	$\$_{18}$	$\$_{19}$	<= $\$\$_1$
Example:	100	85	75	00	50	47	00	70	00	<= 195
	(personnel costs expressed in $1000 units)									
Personnel	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}	a_{17}	a_{18}	a_{19}	<= $\#\#_1$
Example:	6.0	4.5	4.0	0	4.0	3.5	0	3.0	0	<= 11.0
	(personnel requirements expressed in F.T.E. units)									
Policy 1.0	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}	a_{26}	a_{27}	a_{28}	a_{29}	>= b_2
Example:	4.7	3.6	2.3	1.9	2.5	2.1	1.3	3.9	3.8	>= 9.0

Fails to Meet Most Requirements	Fails to Meet Some Requirements	Marginally Acceptable (Neutral)	Meets Most Requirements as Defined	Exceeds Most Requirements as Defined
[1]	[2]	[3]	[4]	[5]

Policy 2.0	a_{31}	a_{32}	a_{33}	a_{34}	a_{35}	a_{36}	a_{37}	a_{38}	a_{39}	>= b_3
Example:	2.4	2.3	1.5	1.1	4.9	4.5	2.3	3.6	1.0	>= 7.5
	(Scores assessed utilizing 5-point continuum displayed above)									
Opinion	a_{41}	a_{42}	a_{43}	a_{44}	a_{45}	a_{46}	a_{47}	a_{48}	a_{49}	>= b_4
Example:	5.8	4.7	3.2	2.8	4.7	3.2	3.1	4.3	1.7	>= 16.0

High Negative	Negative	More NEG Than POS	More POS Than NEG	Positive	High Positive
[1]	[2]	[3]	[4]	[5]	[6]

Preference	a_{51}	a_{52}	a_{53}	a_{54}	a_{55}	a_{56}	a_{57}	a_{58}	a_{59}	>= b_5
Example:	25	50	10	15	66	33	1	85	15	>= 198
	(Data represent percents of frequency, where respondents indicated which of the three (3) program scenarios they perceived to be of benefit to the organization en total.)									
Control #1	1	1	1	1						= 1
Control #2					1	1	1			= 1
Control #3								1	1	= 1

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Notice how the criterion of 'personnel' has been modeled in terms of costs (e.g. salaries and fringe benefits) and full-time-equivalent or personnel-unit requirements. In constrast, compliance of each alternative to existing policy is modeled via the use of ordinal measures based upon a previous evaluation of each scenario. The criterion of 'opinion' is synthetic, typically based upon a respondent's perception, and also modeled via ordinal scales. 'Preference' uses a composite measure based upon a previous survey of significant individuals. Finally, the control submatrix assures that (1) each option within a particular program will be evaluated and (2) one and only one funding alternative will be selected for each such program.

While many other illustrations and/or examples are possible, the widely varying budget reduction needs between school districts almost preclude the design of a 'conventional model' which would readily fit every district's needs. The flexibility with which the model can be designed to fit very individualistic needs is both benefit and pitfall. While flexibility allows a model to conform strictly to needs peculiar to any individual modeling situation, this same flexibility forces the developer to re-think the model's formulation for each new budgeting situation, especially as characteristics of supply and demand change to fit the fluid needs of a highly variant society.

DECISION ALTERNATIVES VECTOR FOR DISTRICT CONSOLIATION

The hierarchical district consolidation model is a special case of the Multiple Alternatives Model (MAM™), in as much as it's alternatives vector is composed of both hierarchical and non-hierarchical dependent variables. This modeling formulation may be designed in two ways, depending on the type of information required by the decisionmaker.

The simplest formulation of the district consolidation model requires only three (3) components in the decision alternatives vector: (1) a geocoded distribution subvector, (2) a grade-level distribution (by school) subvector, and (3) a student registration (by school) subvector. These subvectors are arranged linearly as follows:

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x=1	x=2 ... x=n		Grades in Elementary Schools			School
y=1,...,m	y=1,...,m	y=1,...,m	K 1 ... 6	K 1 ... 6	K 1 ... 6	E_1 E_2 E_3

| <----------> |

Geocoded Distribution Subvector
(provides a geographic mapping control over student residence, location of schools, and the availability of students by age and/or grade level)

| <----------> |

Grade-Level Distribution Subvector
(provides an ability to assign students from each geocoded cell to specific grade levels as well as specific school sites)

| <------> |

Student Registration Subvector
(provides for an aggregate control for enrollment, school site building capacities, and later modeling reference for school closure requirements)

While the preceding hierarchical formulation does perform individual geocoded cell assignments for arranging attendance boundaries and testing the enrollment/registration potential for each of the schools (elementary school in the above illustration), the model does not have the ability to inform the decisionmaker which cells were assigned to which school -- a probable limitation. Therefore, while the model will inform the decisionmaker (1) if consolidation is a viable response to retrenchment (e.g. fiscal depletion and enrollment decline) and (2) if any schools might be plausibly targeted for operational discontinuance, it will not denote attendance boundaries for each school.

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An alternate approach -- one which would designate cell-to-school assignments -- is possible through the use of separate geocoded distribution subvectors for each of the schools being modeled. That is,

Elementary School #1		Elementary School #2					
x=1 ... x=n		x=1 ... x=n		Grades in Elem Schs		Sch	
y=1,...,m	y=1,...,m	y=1,...,m	y=1,...,m	K 1 ... 6	K 1 ... 6	E_1	E_2

| <----------> |

(redundant geocoded distribution subvectors for each of the schools being modeled)

Redundant geocoded distributions obviously provide a dilemma to the modeler. If, for example, the geographic boundaries under evaluation represented a geocode matrix of 100 cells (not unlikely) for five schools, then this alternate modeling formulation would require a hierarchical subvector of 500 dependent decisional variables. The simpler formulation would only need the single set of 100 dependent decisional variables. Nevertheless, without the use of separate geocode distributions for each school being evaluated, the model is only partially useful for the complex decisions which will eventually have to be made.

Only the dependent variables of the geocoded distribution subvector are actual decision variables (i.e. of the (1,0) binary format). The remaining dependent variables (of the grade-level distribution and student registration subvectors) are called repository (or slack) variables. Their function is to store intermediate calculations (sums) which will be used subsequently for other calculations. This is the special case of the Multiple Alternatives Modeling (MAM™) formulation, and is typically referred to as a "mixed integer" design.

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THE DISTRICT CONSOLIDATION MODEL

The district consolidation model is markedly more complex than either of the previous school closure and graduated budget reduction (hierarchical) MAM™ formulations. Several different sets of varying types of criteria are required, as well as a comprehensive set of control (value '1' - vectors) submatrices.

For the limited introductory purposes of this paper, the control submatrix of the model will be displayed, wherein two schools (K-6 elementary) are illustrated. The purpose of this control submatrix is multiple: (1) assure that all cell-to-school assignments are recorded by the model for later reporting to the decisionmaker, (2) assure that all assignments are made accurately by appropriate grade-level of student(s), (3) assure that all intermediate summations are stored for later use, and finally (4) assure that all geocoded cells are assigned to one of the schools with no geocoded cell being assigned to more than one school attendance area (i.e. no duplication).

An example formulation of these four modeling objectives might be displayed as follows:

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Elementary School #1		Elementary School #2					
x=1 ... x=n		x=1 ... x=n		Grades in Elem Schs		Sch	
y=1,...,m	y=1,...,m	y=1,...,m	y=1,...,m	K 1 ... 6	K 1 ... 6	E_1	E_2

[RHS]

```
K K ... K  K K ... K                    -1                          =0
1 1 ... 1  1 1 ... 1                      -1                        =0
2 2 ... 2  2 2 ... 2                         ...                     .
3 3 ... 3  3 3 ... 3                                                 .
4 4 ... 4  4 4 ... 4                                                 .
5 5 ... 5  5 5 ... 5
6 6 ... 6  6 6 ... 6                              -1                 =0
| <-------------------------------------------------------------------|
```

(assures that any cell-to-school assignments of student residences for the development of attendance boundaries for elementary school #1 are recorded)

```
                    K K ... K  K K ... K              -1              =0
                    1 1 ... 1  1 1 ... 1                -1            =0
                    2 2 ... 2  2 2 ... 2                   ...         .
                    3 3 ... 3  3 3 ... 3                               .
                    4 4 ... 4  4 4 ... 4                               .
                    5 5 ... 5  5 5 ... 5
                    6 6 ... 6  6 6 ... 6                     -1        =0
                    | <-----------------------------------------------|
```

(assures that any cell-to-school assignments for the attendance boundary of school #2 are recorded)

```
                                  1 1 ... 1              -1            =0
                                            1 1 ... 1      -1          =0
                                  | <-------------------------------->|
```

(assures that all grade-level enrollments are consolidated for later closure applications)

```
1                     1                                               =1
  1                     1                                             =1
    .                     .                                           .
    .                     .                                           .
    .                     .                                           .


                ... 1                 ... 1                           =1
| <-------------------------------------------------------------------|
```

(assures that all geocoded cells are utilized during the assignment process

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and that one and only one such cell assignment is made per school)

As with both the hierarchial school closure and graduate budget reduction models, the district consolidation model contains additional criterion submatrices which allow the use of evaluative standards for performing the various cell assignments under optimization. Such criteria would allow the control of minority concentration assignments (e.g. desegregation compliance) and the allocation of special education program services (e.g. "magnet school" designation).

SUMMARY AND RECOMMENDATIONS

Historically, the MAM™ approach has been applied to elementary school closures and budgeting reductions within public school districts. Other models which have been developed include the matching of instructional activities to market-available microcomputer hardware and software, and the reconfiguration of primary, elementary and secondary grade levels, by building, for medium-sized school districts, as well as the consolidation and merger of rural school districts previously discussed.

The model's initial formulation in 1978 identified a total of five (5) elementary schools from a field of 32 schools for closure. Further research using the graduated budget reduction model during 1981-83 demonstrated that the model effectively and efficiently targeted the appropriate programs and their respective level of reduced funding, based upon the criterion references supplied to guide the decisionmaking process. Post-hoc statistical analyses which matched the data used to the results generated significantly validated the model's technique and simulation processes.

Certainly, no computer simulation technique or mathematical model should be placed in a position to make the decision for the district administrator, for example, in the case of targeting district schools for closure. However, this is not to say that such a data analysis and alternatives evaluation technique should not be used to compare the multiple of options available to the decisionmaker, and to provide more composite information for the final decision process.

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If school closure is a rational albeit controversial option, the decisionmaker might at least desire to know "If so, which ones and how many?".

Recent experiences further demonstrate that education, given its more exclusive authority over its own destiny, has been unable to deal adequately and decisively with fiscal emergencies. Declining enrollments, the resulting loss of revenues, and the increasingly marginal character of its faculty have mitigated against the university's attempts to better itself, its destiny and its mission in an ever changing society.

Educational administrators have been unable to analyzed adequately the mass of available data which could shed some light on which programs could be reduced, and by how much. At the same time, these administrators need to know which programs require additional monies in order to continue their appointed, effective mission. It is the contention of this paper that the multiple alternatives modeling™ formulation for identifying graduated budgeting reductions for each university program provides the basis for a more appropriate and adequate response on the part of higher educational administrators to fiscal exigency.

The graduated budgeting scheme of MAM™ provides a scientific, data based and bias-controlled approach to targeting program budgets for reduction. While the model is complex to the novice, it is easily learned, employed and executed, given the availability of the appropriate computer software. Effectively, hundreds of higher educational programs (instructional, service and/or administrative) can be compared and contrasted through the use of hundreds of criterion references in order to identify appropriate levels of budgeting reductions (or increases) for each of the programs evaluated.

Research on the graduated budgeting model during 1981-83 demonstrated that the model effectively and efficiently targeted the appropriate programs and their respective level of reduced funding, based upon the criterion references supplied to guide the decisionmaking process. Post-hoc statistical analyses which matched the data used to the results generated significantly validated the model's technique and simulation processes.

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